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THE

MEDICAL STUDENT'S

ESSENTIALS OF PHYSICS,

BY

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BOOK I.

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CHAPTER I.

Physics treats of the phenomena presented to us by matter.

Matter is anything we can appreciate by our senses, and is made up of *sixty-seven elements* or substances that cannot be divided into other substances.

PROPERTIES OF MATTER.

a. *Impenetrability.* The property of occupying space exclusively.

b. *Extension or volume.* The space matter occupies.

c. *Form.* The definite shape of matter.

d. *Indestructibility.* The inability to destroy matter even though it may change its form.

e. *Elasticity.* The tendency for matter to return to its original form or volume when the force that altered its shape ceases to act.

DIVISION OF MATTER.

Matter may be divided into:—

Atoms.

Molecules.

Masses.

a. An *Atom* is the smallest division of matter and unite to form molecules.

b. A *molecule* is the smallest group of atoms that will exhibit the physical and chemical properties of the substance and cannot be divided without losing these characteristics.

c. A *mass* is a collection of molecules.

Molecules present themselves in three different states, as—

Solids.

Liquids.

Gases.

a. In a *Solid state* the molecules are naturally in a fixed condition and as a consequence solid bodies tend to retain a given form.

b. In the *Liquid state* the molecules move freely upon each other.

c. In the *Gaseous state* the molecules tend to repel each other or to occupy greater space.

FORCES GOVERNING MATTER.

1. Force controlling atoms.

a. *Chemical affinity* or that force which causes atoms to combine or to remain combined.

2. Forces controlling molecules,
   Cohesion,
   Adhesion,
   Repulsion,
   Polarity.

a. *Cohesion* is that force which unites molecules to form masses.

b. *Adhesion* is the molecular force which binds together the surfaces of two or more masses.

c. *Repulsion* is that force which causes molecules to occupy more space.

d. *Polarity* is that force which unites molecules to form crystals.

3. Force controlling masses.

Gravitation is the force attracting masses to each other and is governed by the following law.

The attraction is directly in proportion to the mass and inversely as the square of the distance.

Gravity is the force exerted by the earth upon a body.

SPECIFIC GRAVITY.

Specific Gravity or Density is comparative weight.

The standards for comparison are—*for liquids and solids*, water at a temperature of 60° F. and for *gases* and *vapors*, air or hydrogen.

The principle by which we obtain the specific gravities of substances, depends upon the law of Archimedes. *A body immersed in a liquid loses weight equal to the weight of the liquid displaced.*

CHAPTER II.

LIQUIDS.

Liquids are but slightly compressible and according to Pascal's law—*Pressure is transmitted undiminished in all directions, and at right angles to all equal surfaces.*

1. Means of obtaining specific gravity of solids.

By Hydrostatic balance. Weigh the substance first in air, then in water, and divide its weight in air by its loss of weight in water. The result is its specific gravity.

2. Of Liquids.

a. *By the specific gravity bottle.*

Subtract the weight of the bottle from the weight of the bottle filled with water and then from the weight of the bottle filled with the liquid, and divide the latter by the former, the result is its specific gravity.

b. *By the hydrometer*, which consists of a graduated glass tube loaded at the bottom with mercury so it may sink to a certain depth in fluids, the depth depending upon the specific gravity of the substance.

CHAPTER III.

GASES.

In gases the molecules tend to expand or repel each other. *Otto Degarager* first established the fact that gases had weight.

The pressure or weight of the atmosphere at the level of the sea is about fifteen pounds to the square inch, but diminishes proportionally as we ascend.

Torricelli's experiment.

Torricelli first determined the pressure of the atmosphere by taking a glass tube sealed at one end, filling it with mercury and inverting it by placing the open end covered with the thumb in a vessel of mercury.

He found by this experiment that the mercury in the tube remained about thirty inches above the level of the mercury in the vessel and the weight of this mercury represented the pressure of the atmosphere to be in proportion of fifteen pounds to the square inch.

The Torricellian vacuum is the space above the mercury in the tube.

Pascal determined that the height of the mercury in the tube really did depend upon the pressure of the atmosphere, for performing the same experiment on a high mountain, he found the mercury did not remain so high.

BAROMETERS.

Barometers are instruments used for measuring atmospheric pressure.

Many of them are based on the principle of Torricelli's experiment—the pressure of the atmosphere being measured by the height of a column of mercury.

BAROMETRIC CORRECTIONS.

Corrections have to be made in mercury barometers for :—

Temperature.

Elevation.

Capillarity.

State of weather.

a. *Temperature* causes either contraction or expansion of the mercurial column itself.

b. *Elevation* above the level of the sea causes the column to fall.

c. *Capillarity* causes the mercury to adhere to the sides of the tube.

d. In dry *weather* the atmosphere is dense and consequently the pressure on the mercury causes it to stand higher than it does in wet weather when the air is rarer and contains more aqueous vapor.

AIR BAROMETERS.

Beside fluid barometers there are air barometers, *Aneoid's* being a good example.

This consists of a thin metallic box exhausted of air, the top of which is so thin that it yields readily to alterations in the pressure of the atmosphere. These alterations are transmitted by levers to an index which indicates the pressure on a scale.

LAW OF GASES.

a. *Boyles' Law. The volume of a gas is inversely as the pressure.*

b. *The rapidity with which gases mix is inversely as the square root of their density.*

c. *The density of a gas is directly as the pressure.*

SPECIFIC GRAVITY OF GASES.

Weigh the same volume of air and the gas and divide the weight of the gas by that of the air. The result is the specific gravity of the gas.

AIR PUMPS.

The principle of the air pump depends upon the expansive or repulsive property of gases.

We take away a portion of air and the remainder expands so as to fill up the whole space.

In this way the air becomes greatly rarified, but an absolute vacuum cannot be produced.

In *Sprengel's* air pump which depends upon the principle of converting the space to be exhausted into a *Torricellian vacuum*, falling mercury passes the aperture of the vessel to be exhausted of the gas.

The gas as it were is entangled in the falling mercury and in this way a nearly complete vacuum is produced.

It is on the principle of Sprengel's air pump, that traps in water pipes are syphoned, thus leaving the pipes free to allow the passage of sewer gas.

BOOK II.

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CHAPTER I.

HEAT.

Theories.

1. *Emission Theory.* Heat is considered an imponderable fluid which surrounds all molecules and the entrance of this fluid into substances causes heat and its egress cold.

2. *Undulatory Theory.* Heat is due to a rapid vibratory movement of the molecules of any substance. That all space is filled with an imponderable ether which hot bodies set in rapid vibration, thus communicating a more rapid vibration to the molecules of adjacent substances.

This theory is the one generally adopted.

TEMPERATURE.

Heat causes all substances to expand, hence by the different expansive qualities of liquids, solids and gases, we can measure temperature.

Temperature is the greater or less extent a substance tends to impart sensible heat to other substances.

THERMOMETERS.

Temperature is measured by thermometers. Liquid thermometers are generally used—mercury and alcohol being the best suited for this purpose. Mercury, because it boils only at a very high temperature, and alcohol because it does not freeze even at the lowest temperatures.

MERCURY THERMOMETERS.

In constructing an ordinary mercury thermometer, two fixed points are determined for graduation—viz:

a. Boiling point of water at the level of the sea.

b. Freezing point of water.

As these two temperatures are constant and the expansion of mercury is nearly uniform, the graduation of the thermometer is accomplished by dividing the space between the freezing and boiling points of water into an equal number of parts called degrees.

The size of these degrees differ in various countries.

In this country the *Fahrenheit* scale is used--freezing point 32°—boiling point 212°.

In France and on the Continent generally, the *Centigrade* scale—freezing point taken as 0° and boiling point 100°.

In some portions of Germany the *Reaumure* scale is chiefly used--the freezing point being 0° while the boiling point is taken at 80°.

CONVERSION OF DEGREES.

1. Fahrenheit to Centigrade.

$(F—32°) \frac{5}{9} = C.$

2. Fahrenheit to Reaumur.

$(F. — 32°) \frac{4}{9} = R.$

3. Centigrade to Reaumur.

$\frac{4}{5} C = R.$

4. Centigrade to Fahrenheit.

$\frac{9}{5} C + 32 = F.$

5. Reaumur to Fahrenheit.

$\frac{9}{4} R + 32 = F.$

6. Reaumur toCentigrade.

$\frac{5}{4} R. = C.$

ALCOHOL THERMOMETERS.

Alcohol thermometers are used for determining low temperatures only, for alcohol boils at 78° C. and as it nears the boiling point it expands very irregularly thus destroying its accuracy for high temperatures. As mercury freezes at 40° C. and alcohol does not freeze at the lowest temperatures, it is here that alcohol thermometers are found so useful.

They are graduated by means of comparison with the mercury thermometer at different degrees of temperature.

AIR THERMOMETERS.

Air thermometers are based on the expansion of air by increase of temperature. This expansion is denoted by the rise and fall of a colored liquid in the tube of the thermometer. The graduation of the scale is made by comparing the position of the fluid with the indications of a mercury thermometer at equal temperatures.

Thermometers may be

Delicate.

Accurate.

a. A *delicate* thermometer is one that

measures rapidly very small changes of temperature.

b. A thermometer is *accurate* when it indicates the changes of temperature correctly.

PYROMETERS.

Pyrometers are instruments used for measuring very high temperatures. They are various in kind.

a. Some are made of metals that melt at a known temperature.

b. Others depend upon the principle of the air thermometer.

c. Still others on the electric thermometer—higher the temperature the better the conductility.

CHAPTER II.

EXPANSION.

1. *Of Solids.*

Solids expand in three dimensions.

a. Linear.

b. Superficial.

c. Cubical.

The *co-efficient* of expansion is the expansion due to the rise of temperature from 0° to 1° C. The co-efficient of expansion in solids vary to a marked degree, and from this fact many applications are made.

Thus in the *compensation pendulum* the distance between the center of oscillation and the center of suspension remains constant at all temperatures by properly using metals with different degrees of expansibility, in its construction.

2. *Of liquids.*

The *co-efficient* of expansion of a liquid is the increase of the unit of volume for a single degree.

With an increase of temperature there is

an increase of volume. In water however if the temperature fall below 4° C. it expands till the freezing point is reached.

Hence the maximum density of water is at 4° C.

3. *Of gases.*

The *co-efficient* of expansion of a gas is its increase of volume for 1° C.

This co-efficient is nearly uniform for all gases at all degrees of temperature.

Gases expand $\frac{1}{273}$ of their volumes for each degree Centigrade.

CHAPTER III.

FUSION.

Fusion is the passage of a body from the solid into the liquid state.

Every substance begins to fuse at a certain temperature and that temperature remains the same until fusion is complete.

All substances that expand on passing from the solid to the liquid state, as the great majority do, any increase in pressure will raise the melting point. The reverse is true in all substances—such as ice, that contract during fusion.

LATENT HEAT.

Latent heat is that heat which causes *change of state* or fusion and is not indicated by the thermometer. Thus if one pound of water at 80° C. be mixed with one pound of ice at 0° C. the result will be water at 0° C. Hence it takes as much heat to melt one pound of ice as will raise one pound of water 80° C. Therefore 80° C. is called the latent heat of water.

During solution a quantity of heat becomes latent. It is on this principle of fusion that artificial cold is produced.

In passing from a solid to a liquid state a certain amount of heat is required and the extraction of this heat from surrounding substances lowers their temperatures.

Chemical affinity accelerates fusion, hence acid and a salt or ice and salt acting in this way are better freezing mixtures than a salt or ice alone would be.

CHAPTER IV.

VAPORS.

Vapors are aeriform fluids into which volatile substances are changed by the absorption of heat.

Vapors are transparent and usually colorless. *Vaporization* is the rapid passage of a liquid into the gaseous state.

Evaporation is the slow production of vapor from the free surface of a liquid.

Under ordinary conditions liquids pass but slowly into the gaseous state, but in a vacuum all volatile liquids are immediately converted into vapors.

Heat also hastens vaporization.

Saturated vapors. When a vapor is so dense that any increase of vaporization or pressure, or any decrease of temperature, will cause a portion of it to assume a liquid state the vapor is said to be *saturated.*

The higher the temperature the more vapor it takes to reach the point of saturation.

Tension. The pressure exerted by a gas is called its tension, The tension of a gas is measured by the pressure it exerts on a column of mercury. Increase the temperature and the tension of a gas is increased proportionally.

Boiling is the rapid production of bubbles of vapor in the mass of liquid itself. Boiling takes place when the tension of its vapor is equal to the pressure of the atmosphere, hence any increase in the pressure will raise the boiling point, and any diminution in the pressure will lower the boiling point.

The former fact is made use of in *Papin's digestor* and in the *patent soup kettles.*

The boiling point is the temperature at which a liquid boils.

EVAPORATION.

Evaporation is aided by

a. Heat.
b. Dryness of surrounding atmosphere.
c. Increase of surface.
d. Renewal of atmosphere.

LATENT HEAT OF VAPORS.

As it requires a certain amount of heat

not indicated by the thermometer to turn a solid into a liquid, so it does to convert a liquid into a vapor.

The latent heat of evaporation of water is 540° C, and this heat has to come from surrounding substances, such as heat produced by rapid combustion, &c. Hence evaporization produces cold, and by appropriate apparatus water, mercury, &c., can be frozen by it.

LIQUEFACTION OF VAPORS AND GASES.

Liquefaction of vapors and gases is accomplished by means of

a. Cold.
b. Pressure.
c. Chemical affinity.

Distillation is an example of liquefaction of vapors by means of cold. All gases such as Hydrogen, Nitrogen and "Laughing Gas" can be liquefied by pressure.

SPHEROIDAL CONDITION.

When a drop of water is thrown upon a red hot surface, as iron, it does not boil or rapidly evaporate, but forms a globule that rotates rapidly over the iron. This is called *spheroidal state* and is due to the globules

resting upon a cushion of its own vapor produced by the heat radiating from the hot surface to its under surface. Many liquids have a spheroidal state.

CHAPTER V.

HYGROMETRY.

Hygrometry is determining the quantity of aqueous vapor contained in a given quantity of air.

The air is never saturated, but the ratio of the quantity of aqueous vapor to the atmosphere when saturated is called the *hygrometric state.*

There are a number of instruments made for determining this state called *hygrometers.*

These are,

Chemical hygrometers.

Condensing "

Absorbing "

Psychrometers.

a. *Chemical hygrometers* are based on the property that some substances have of absorbing all the water in the air passed through them.

The substance, such as the chloride of calcium having been weighed before and af-

ter the passage of the air through it, the difference in weight represents the amount of aqueous vapor present.

b. *Condensing hygrometers* are based upon the fact that if the temperature of the atmosphere is lowered, at a certain degree the point of saturation will be reached.

This temperature at which the air is saturated is called the *dew-point*.

By comparing the temperature of the surrounding atmosphere and the dew-point, and dividing the tension of the atmosphere at dew-point by the tension of the surrounding air at the given temperature, will give the hygrometric state of the air.

c. *Absorption hygrometers* are based upon the property which some organic substances have of elongating when moist, and shortening when dry.

d. The *Psychrometer* or *wet-bulb hygrometer* is based upon the fact that a fluid evaporates more rapidly in the air, in proportion as the air is drier, and consequently the temperature of the fluid falls in the same proportion.

The instrument consists of two thermo-

meters, the bulb of one covered with wet muslin.

The nearer the air is to being saturated the nearer the two thermometers will indicate—the wet-bulb thermometer always indicating the lower temperature.

CHAPTER VI.

TRANSMISSION OF HEAT.

Heat is transmitted by

Radiation.

Conduction.

Convection.

a. *Radiated heat* is that which is transmitted to a body from the source of heat without affecting the temperature of the intervening medium and *its intensity is inversely as the square of the distance and directly as the temperature of its source.*

Bodies that transmit radiated heat readily are called *Diathermanic*, while those that stop radiated heat, *Athermanic*. Bodies that absorb the most heat are the best radiators, the two properties being equal.

b. *Conducted heat* is that which is transmitted in the mass of the body itself. Bodies conduct heat with very different degrees of facility. Metals are the best conductors while organic substances and liquids are

poor conductors. Gases conduct heat very little if at all.

c. *Convected heat* is that which is transmitted in liquids. When liquids are heated at the bottom, ascending and descending currents are produced by the heated layers becoming less dense and rising while the denser and colder layers above sink to the bottom. This method of transmitting heat is called *convection.*

REFLECTION OF HEAT.

The laws governing the reflection of heat are like those of light, (*See chapter on light.*)

Some bodies have much greater reflecting power than others. Metals have the greatest and lamp-black the least.

White bodies reflect heat well but absorb little; the reverse is true of black substances.

CHAPTER VII.

CALORIMETRY.

Calorimetry is the measure of the quantity of heat a body loses or gains during change of state or temperature.

Quantities of heat in substances are expressed by the extent of their power to raise the temperature of a known quantity of water.

A *Thermal unit* is the standard of comparison for quantities of heat, and is the amount of heat necessary to raise one pound of water 1° C.

Specific heat is the quantity of heat it takes to raise different substances to the same temperature, and is determined in three ways:

a. By melting ice.
b. By mixtures.
c. By cooling.

The *melting ice method* is based upon the fact that it takes to melt one pound of ice 80 *thermal units*. This gives a standard for comparison, as some substances will take

more thermal units than others to melt the ice.

By mixtures. A known weight of the substance whose specific heat is required is heated to a certain temperature and then immersed in water whose quantity and temperature are known. From the temperature of the water after mixing, the specific heat is determined.

The *cooling method* is based upon the fact that bodies of different specific heat will occupy different lengths of time in cooling through the same number of degrees. Those that have the greatest specific heat will take the longest to cool. Water and fluids in general have greater specific heat than metals.

The specific heat of water is taken as *unity*.

The specific heat of substances increases with the temperature, and especially as they near their fusing point or change of state.

CHAPTER VIII.

SOURCES OF HEAT AND COLD.

Sources of heat:

1. *Mechanical.*

Compression.

Friction.

Percussion.

Heat due to percussion is not the result of compression, but to a vibratory motion given to the molecules.

2. *Physical.*

a. Solar radiation.

b. Terrestrial heat.

c. Electricity.

d. Change of state.

At a certain depth below the surface of the earth there is a constant temperature below this the temperature increases on the average of 1° C. for every ninety feet of descent.

3. *Chemical.*

a. Combustion.

b, Animal heat.

c. Vegetable heat.

The *heat* of combustion depends upon the *quantity*, while the *temperature* upon the *rapidity*, of the combustion.

Vegetable heat is more marked in plants at the time of blossoming when oxidation accompanies the process.

The process of *vegetation* in general is not accompanied by heat for it is not an oxidation.

Under the influence of the sun's rays the green parts of the plant decomposes the carbonic acid in the atmosphere into oxygen and carbon which unite with the elements of water to form cellulose, sugar, starch, &c. To effect this, heat is required which is stored up in the plant and reappears during combustion of wood, coal, &c., arising from its decomposition.

SOURCES OF COLD.

a. Change of state.
b. Expansion of gases.
c. Radiation.

Especially nocturnal radiation.

CHAPTER IX.

MECHANICAL EQUIVALENT OF HEAT.

Heat is the result of motion, and it is found, in all cases in which motion is the direct producer of heat, that mechanical force is consumed.

By numerous experiments it has been found that the *mechanical equivalent* of heat is 772 foot pounds Fahrenheit scale or 1390 foot pounds Centigrade scale.

In other words heat and mechanical energy are convertible and heat requires for its production, and produces by its disappearance, mechanical energy in the ratio of 772 foot pounds for every thermal unit.

WORK OF ENGINES.

Multiply together the mean pressure on the piston, the area of the piston and the length of stroke the result will equal the *working power* of the engine.

This work is compared to *horse power* which represents 550 *foot pounds* raised one foot per second.

A *foot pound* is the work necessary to raise one pound a foot high.

BOOK III.

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CHAPTER I.

LIGHT.

Theories.

1. *Emission theory.* This theory assumes that all luminous bodies emit an imponderable substance which penetrating the eye acts upon the retina causing vision.

2. *Undulatory theory.* This theory assumes that all space and substances are filled with a luminiferous ether and the luminosity of any body is due to the rapid vibratory movement of its molecules, thus setting in motion this ether which in turn acting upon the retina of the eye causes vision.

The undulatory theory is the one usually adopted.

PROPAGATION OF LIGHT.

Bodies may be :—

Luminous.

Transparent.

Translucent.

Opaque.

a. *Luminous bodies* are those that admit light.

b. *Transparent bodies*, those that transmit light so objects can be distinguished through them.

c. *Translucent bodies*, those that transmit light imperfectly so that objects are not distinguishable through them.

d. *Opaque bodies* are those that do not transmit light.

A *luminous ray* is the direction of the line in which light is propagated.

A *pencil of light* is a collection of rays.

Rays of light may be :—

a. Parallel.

b. Divergent.

c. Convergent.

A *homogeneous medium* is one whose chemical composition and density is the same in all parts. In homogeneous mediums light is propagated in straight lines.

SHADOWS.

Shadow is the space behind an opaque body upon which light is thrown.

Penumbra is the dark space around the true shadow of an object, and is due to the light coming from a source greater than a single point.

VELOCITY of LIGHT.

The *velocity of light* has been obtained by means of astronomical observations in noting the difference in time of occultation of one of Jupiter's moons when the earth is on opposite sides of its orbit.

This difference has been found to be 16′—36″, which represents the time it takes light to travel across the earth's orbit and gives for its velocity nearly 190.000 miles a second.

CHAPTER II.

INTENSITY OF LIGHT.

The following law governs the intensity of light.

The intensity of light is inversely as the square of its distance from the source of light

Photometers are instruments for measuring the relative intensities of light.

The sperm candle burning two grains per minute is taken as the standard for this measurement.

Most photometers as *Rumford's* and *Bunsen's* are made upon the principle that to obtain equal shadows light must be of the same relative intensity. Therefore by placing the sources of light nearer or farther away from the object casting the shadows until they—the shadows are equal; the intensity of the light is determined by the law that the intensity of light varies inversely as the square of the distance.

Thus if one light is a foot away and a se-

cond light two feet away from the object casting equal shadows, the light two feet distant has four times the intensity of the one only a foot away.

CHAPTER III.

REFLECTION OF LIGHT.

The reflection of light is governed by the following law.

The angle of reflection is equal to the angle of incidence both rays being in the same plane and perpendicular to the reflecting surface.

By drawing a perpendicular to the reflecting surface at the point where the rays meet it, the *angle* of *incidence* is the angle these rays make with the perpendicular, while the *angle of reflection* is the angle reflected rays make with the perpendicular.

The intensity of the reflecting power of a body increases with the degree of polish and with the obliquity of the incident ray.

REFLECTING SURFACES.

Mirrors are bodies with polished surfaces which show by reflection, objects presented to them. The image is the place where the objects appear.

The surfaces of mirrors are :—

Plane.

Curved.

I. *Plane mirrors.* In plane mirrors the image is formed behind the mirror at a distance equal to that of the object forming it, and on the perpendicular let fall from this object to the mirror. The image is *erect*, *virtual* and *equal* in size to the object forming it.

A *virtual image* is one formed by the prolongation of the reflected rays and not by these rays themselves.

A *real image* is one formed directly by the reflected rays, and not by their prolongation.

Multiple images are formed by proper arrangement of several mirrors, as for example in the kaleidoscope.

II. *Curved Mirrors.* Curved mirrors may be :—

Spheroidal.

Parabolic.

A. *Spheroidal mirrors.* The *centre of curvature* is the centre of the sphere of which the mirror forms a part.

The *principal axis* is the line drawn from the centre of curvature to the centre of the mirror.

The *secondary axis* is a line drawn from the centre of curvature to any point on the mirror.

The *focus* is the point at which the reflected rays meet.

The *principal focus* is the point where reflected, parallel rays meet.

The *conjugate focus* the point where other than parallel reflected rays meet.

Spheroidal mirrors are :—

Concave.

Convex.

a. In *concave mirrors* which tend to *converge* all reflected rays, the principal focus is situated midway between the centre of curvature and the mirror.

The position of the image depends upon the relation of the object to the mirror.

1. If the object is at such a distance that the rays from it are parallel, the image will be situated at the principal focus—*real, smaller* than the object, and *inverted.*

2. If the object is beyond the centre of

curvature, the image will be *real, inverted, smaller* than the object itself and situated between the centre of curvature, and the mirror.

3. If the object is between the centre of curvature and mirror but nearer the centre of curvature, the image will be *real, inverted, larger* than the object and beyond the centre of curvature.

4. If the object is between the centre of curvature and mirror but near the mirror, the image will be *erect, virtual* and *larger* than the object.

b. In *convex mirrors*, all reflected rays tend to *diverge*, whatever be the position of the object in relation to the mirror the image is always *virtual, erect* and *smaller* than the object itself.

B. Parabolic mirrors.

In *parabolic mirrors*, when the light is placed at the principal focus the reflected rays are nearer parallel than they are in the simple concave mirrors. The light thus reflected maintains its intensity for a greater distance, for it is the divergence of the rays that diminishes the intensity of light.

Parabolic mirrors are used as head-lights in engines, for lantern reflectors, &c., on account of the reflected rays being parallel and hence maintaining their intensity.

SPHERICAL ABERRATION.

When concave mirrors are large the rays that are reflected from near the edges meet the axis of the mirror nearer the mirror than those that are reflected from the central portions. As a result the image is not precise or there is *spherical aberration* by reflection.

CHAPTER IV.

REFRACTION.

Refraction of light is the bending of the ray of light in passing from one medium to another.

In passing from a denser to a rarer medium the ray is bent from a perpendicular drawn to the surface of the medium at the point of emergence, but toward the perpendicular in passing from a rarer to a denser medium.

There is also in refracted light an *angle of incidence and refraction.*

If a perpendicular be drawn to the surface separating the two media at the point where the rays enter it, the *angle of incidence* is the angle made by the ray and the perpendicular; and the *angle of refraction* is the angle made by the prolongation of the perpendicular and the bent ray as it passes through the second medium.

The incident and refracted rays are in the

same plane and perpendicular to the surface separating the two media.

Most substances only refract the incident ray once, but some crystalline bodies cause *double refraction.*

The *index of refraction* is the ratio between the sines of the incident and refracted angle. When a luminous ray passes from a greater to a less refracting medium, at a certain obliquity of the ray the angle of incidence is so great that the refracted ray emerges parallel to the separating surface, and the *critical angle* is the angle this oblique ray makes with the perpendicular. Any greater obliquity of the incident ray will cause *total reflection* and none of the rays will pass out of the first medium.

MIRAGE.

Mirage is an optical illusion by which inverted images are seen as if below ground or in the atmosphere. It is a phenomena of refraction and due to the unequal density of different layers of air when they expand by contact with the heated soil—the least dense rays being the lowest.

CHAPTER V.

TRANSMISSION OF LIGHT.

Light may be transmitted through :—

Media with parallel faces.

Prisms.

Lenses.

I. When light is transmitted through media with *parallel faces* the emergent rays are parallel to the incident rays.

II. A *prism* is any transparent medium between faces inclined to each other. Any ray of light passing through a prism is refracted twice in the same direction, once in passing into the prism and then again on emergence.

The *angle of deviation* is the angle this emergent ray makes with the incident.

III. *Lenses* may be considered as made up of a number of prisms. Lenses are named from their shape :—

Convex.

Plano-convex.

Concave.

Plano-concave.

Diverging concavo-convex.

Converging concavo–convex.

The curved surface of lenses are arcs of circles.

The *focus* of a lens is the place the refracted rays meet.

The *real focus* is that formed on the opposite side of the lens from the luminous rays.

The *virtual focus* is that formed on the same side of the lens as the luminous rays.

In *convex lenses* the *principal focus* or the point where parallel rays meet corresponds nearly to the centers of curvature of the lens. Convex lenses tend to *converge* all luminous rays passed through them.

The position of the image depends upon the distance away the object is from the lens.

a. If the object is at such a distance that the rays proceeding from it are parallel, the image will be *real, inverted, smaller* than the object and situated at the centre of curvature of the lens.

b. If the object is beyond the centre of

curvature the image will be *real, inverted, smaller* than the object and situated a little beyond the principal focus.

c. If the object is just beyond the centre of curvature the image will be *real, inverted, larger* than the object and situated some distance beyond the principal focus.

d. If the object is between the centre of curvature and the lens the image will be *virtual, erect, larger* than the object and situated beyond the principal focus.

Concave lenses. All rays passing through concave lenses tend to *diverge*, hence the image is always *erect, virtual* and *smaller* than the object.

SPHERICAL ABERRATION IN LENSES.

When the lens is large the rays which are transmitted near the edge reach a focus nearer the lens than those rays which pass through near the axis, consequently the image is indistinct or there is *spherical aberration* by refraction.

CHAPTER VI.

DISPERSION AND ACHROMATION OF LIGHT.

When white light or that which reaches us from the sun passes from one medium into another it is decomposed into several kinds of light. This decomposition is called *dispersion of light.*

Thus if a pencil of solar light pass through a prism and be thrown upon a screen, seven principal colors are pictured there which are from above downward, violet, indigo, blue, green, yellow, orange and red. These colors thus produced are called the *solar spectrum.* The violet is the most refrangible color, and the red the least.

The spectra formed by artificial light seldom contain all the colors of the solar spectrum, but those present are invariably in the same order as those composing that spectrum. The colors of the spectrum are *simple,* that is they cannot be further decomposed. If however the various colors

are recombined the result is white light again.

The *color of bodies* depends upon the fact that one portion of the colored rays contained in white light is absorbed, while the other portion is reflected, giving them their color.

The bodies that reflect all the colors are white while those that reflect none are black, *mixed colors* are those produced by a combination of two or more colors.

Complimentary colors are those which when combined produce white. *Homogeneous light* is light containing but one color or *monochromatic light.*

Common salt burnt in Bunsen's lamp gives nearly a homogeneous light.

PROPERTIES OF THE SPECTRUM.

a. *Luminous properties.* Light in the yellow portion of the spectrum has the greatest and in the violet, the least intensity.

b. *Heating properties.* The hottest portion of the spectrum is just beyond the red, but depends somewhat upon the kind of prism used to effect the dispersion.

c. *Chemical properties* are more marked just beyond the blue portion of the spectrum.

DARK LINES IN THE SPECTRUM.

The color of the solar spectrum is not continuous, but for several grades of refrangibility rays are wanting and in consequence it contains many dark lines. These lines are always in the same position.

In spectra of artificial lights and stars the positions of the dark lines are changed or replaced by bright ones, when compared with the solar spectrum.

Fraunhofer's lines is the name given to the most marked dark lines in the solar spectrum, and are designated by letters of the alphabet.

A very delicate means of detecting some of the ingredients in unknown substances, is afforded by volatilizing a portion of the substance in a flame and denoting the color it imparts to certain of Fraunhofer's lines.

This method of examination is called *spectrum analysis.* It has been ascertained that whenever salts of the same metal are introduced into a flame they always produce lines identical in color and position.

SPECTROSCOPE.

The *spectroscope* is an instrument used for the study of the spectrum and is composed of three telescopes mounted upon a common footing. The spectra are formed by burning the substance to be examined in front of two of the telescopes by means of a Bunsen burner, which gives but little light of its own, and thus does not obscure the lines in the spectrum to be produced.

The spectra thus formed are brought by means of a prism so they may both be seen by looking through the third telescope and a comparison made, thus detecting the substance under examination by means of their bright lines. *For example* if sodium is suspected of being present in a given substance, burn a portion of it in a Bunsen flame in front of one of the telescopes, and a little sodium in front of the other, and if the bright lines of the two agree the supposed substance is present. *Or*, by comparing the spectrum of the given substance by the solar spectrum, and finding a very bright yellow line or band in exactly the same position as Fraunhofer's line D. and part of the colors absent, sodium is present for *incandescent*

vapors have the power of absorbing rays of the same refrangibility as they admit, and sodium spectra produce just such a dark line as D. when its rays are transmitted through incandescent sodium vapor.

It is by this property of incandescent gases that explains the dark lines in the solar spectrum and lead us to believe that the sun is surrounded by incandescent gases which absorb the rays produced by the luminous properties of the same incandescent substance in the sun. The spectroscope is also used in detecting certain fluid as blood and bile.

This is done by placing some of the fluid between the source of light and the spectroscope. The spectrum thus produced has characteristic dark bands depending on the kind of fluid.

KINDS OF SPECTRA.

Continuous.

Discontinuous or band.

Absorption.

a. *Continuous spectra* are those formed by ignited fluids and solids.

Discontinuous or band spectra are those produced by ignited gases.

Absorption spectra are those produced by the fixed stars and the sun.

FLUORESCENCE.

Fluorescence is that property some substances have of appearing colored when viewed by reflected light, but are colorless when seen by transmitted light.

This property is due to the retardation of the wave movement by the light being reflected and thus brought within compass of the eye.

ACHROMATIC ABERRATION.

Simple lenses when a certain distance from the eye give colored images, due to the unequal refrangibility of the different colors or *achromatic aberration.* To correct this, *Achromatic lenses* or lenses preventing decomposition of light are used, and made by combining lenses of different substances such as crown and flint glass.

CHAPTER VII.

OPTICAL INSTRUMENTS.

Among the most important optical instruments are the : —

Microscope.

Telescope.

Magic Lantern.

Camera Obscura.

a. The *simple microscope* consists of a single convex lens of short focal length the object being placed between the lens and its principal focus. As a result there is produced an *erect*, *magnified* and *virtual* image. The *compound microscope* in its simplest form consists of two convex lenses. The one nearest the object is called the *object glass* or *objective* and has a short focus, the other is called the *eye piece* or *power* and has a longer focus or is less condensing.

The object has to be placed very near the objective, at or near its principal focus. This forms a *real*, *magnified* and *inverted*

image which in turn is magnified by the eye-piece as is the object in the simple microscope.

b. *Telescopes.* In *astronomical telescopes* there is an object glass and an eye-piece. The object is beyond the principal focus of the objective, hence a *smaller*, *inverted* and *real* image is formed which is magnified by the eye-piece as in the compound microscope.

The *terrestrial telescope* differs from the astronomical in producing images in their proper positions. This is effected by means of two convex lenses placed between the objective and the eye-piece so that the image when magnified by the eye-piece will appear erect.

In *Galileo's telescope* on the principle of which *opera glasses* are constructed, the eye-piece consists of a double concave lens which gives at once an erect image and in this way differs from the astronomical telescope. The eye-piece is so placed that the image formed by the objective would fall behind it, if it were not that the rays in passing through the eye-piece are refracted and diverge, so that the eye which receives

them sees the image *near by*, *magnified* and *erect*.

c. *Magic lantern.* This is an instrument for throwing magnified images upon a screen. The reflected rays of a lamp are made to fall upon a convex lens which concentrates them upon the object to be magnified.

A double convex lens is then placed at a little more than the principal focal distance from the object and consequently a *real*, *magnified* and *inverted* image is produced on the screen.

d. *Camera obscura*, consists of a dark chamber with a small aperture to admit the light.

The rays proceed from external objects through this opening and form, *small*, *inverted* images of these objects on the opposite wall. The images are made much brighter and clearer by placing a double convex lens in the aperture. Photographs are taken by the Camera.

CHAPTER VIII.

PHOTOGRAPHY.

Photography is the art of fixing images of the camera obscura on substances sensitive to light.

The first real important step taken in photography was by *Daguerre* in 1839, and in honor to him the pictures thus taken are called *daguerreotypes*. A well polished copper plate is made *sensitive* by exposing it to bromine and iodine vapors which form iodide and bromide of silver. This plate is then placed in the camera at the point where the image will be formed and allowed to remain a few minutes thus exposed to the rays of light.

The plate is next exposed to the action of mercurial vapor which deposits metallic mercury only on the parts affected by the light. All other portions of the iodide and bromide of silver are removed from the plate by a solution of hyposulphite of soda

which does not affect the mercury. The plate is then washed with a solution of the chloride of gold which combines with the mercury and increases the lustre of the picture.

Photographs are now taken on glass and then transferred to paper. The glass plate is first coated with collodion impregnated with iodide of potash. This plate is then immersed in a solution of nitrate of silver thus forming on the plate iodide of silver which is very sensitive to light. The plate is next exposed to the light in the camera as in taking the *daguerreotypes.*

A *developer* or solution of protosulphate of iron is then poured over the plate which reduces to the metallic state those parts of the iodide of silver acted upon by the light. The rest of the iodide of silver is washed off the sensitive plate with hypophosphite of soda.

The image thus produced is called the *negative. The positive* picture is obtained by impregnating paper with the chloride of silver placing over it the negative and exposing it then to the direct action of the sun light for some time. That portion of

the chloride of silver on the paper, not acted upon by the light is then removed by a solution of hyposulphite of soda. The lights of the negative are replaced by shades in the positive and vice versa thus making the pictures to a certain extent more natural, taking white, white and black, black.

CHAPTER IX.

DOUBLE REFRACTION.

Some crystals, as iceland spar, have the property of splitting up the ray of light which passes through them, into two parts so that when any object is seen through one of these crystals it appears double.

This property is explained by assuming that ether in *double refracting* bodies is not equally elastic in all directions so that the vibrations at right angles to each other are transmitted with unequal velocities. One of the rays into which the incident ray is divided is called the *ordinary*, as it represents the ordinarily refracted ray, and the other the *extraordinary* ray, as it differs from commonly transmitted light.

The images produced by double refraction are called the *ordinary* and *extraordinary* from the rays that produce them.

The ordinary rays and images, correspond to those of single refraction.

INTERFERENCE OF LIGHT.

When two luminous rays from different sources meet at acute angles the mutual action produced is called *interference of light*, and as a result well marked colors and bands are formed which depend wholly upon the meeting of these rays.

This phenomenon produced by the interference of light is due to the meeting of the waves of luminiferous ether and coming from different sources either weaken or strengthen each other. As the waves of luminiferous ether have different lengths and velocities for each color this interference of two rays consequently causes a different display of colors than would have been produced by either.

The red rays have the longest and the violet the shortest wave lengths.

POLARIZATION OF LIGHT.

Light besides undergoing double refraction is sometimes *polarized*, that is, made to vibrate in one plane only.

Thus if a ray of light which has undergone *ordinary* refraction be allowed to pass through a second crystal it may be divided

into *ordinary* and *extraordinary* rays with unequal intensities, so by rotating the second crystal one ray will disappear entirely and the other increased in brightness. The same is true with the ray which has undergone *extraordinary* refraction if made to pass through the second crystal.

When light is polarized the ordinary and extraordinary rays are polarized in planes at right angles to each other.

MEANS OF POLARIZING LIGHT.

Light may be polarized by—

a. *Reflection*,

b. *Single refraction*, By means of a ray of light passing through a bundle of glass plates.

c. *Double refraction*. By this means of polarizing light two prisms are needed. One is called an *analyser*, for by means of rotating it the ordinary and extraordinary rays are made to appear and disappear, thus indicating that the light is polarized, and the other the *polarizer* by means of which the light is polarized.

The best prisms used for polarization are made of *tourmaline* which has the property

of absorbing the *ordinary* ray, and iceland-spar which also, as in *Nicol's prism*, has the property of transmitting only one beam of the polarized light.

INTERFERENCE OF POLARIZED LIGHT.

When rays of polarized light meet they cause *interference* as do the rays of ordinarily refracted light and as a result are produced fringes of light with various colors, these colors depending upon the planes of polarization.

ROTATORY POWER OF LIQUIDS.

A great many liquids as saccharine solutions, possess the power of rotating the plane of polarized light either toward the right or the left, and by noting the direction and the number of degrees this plane is rotated from its original position the composition of different substances may be detected when chemical analysis fails.

Soleil's Saccharimeter is an apparatus the principle of which is based on the rotatory power of saccharine solutions.

By noting the number of degrees any given saccharine solution causes the plane of polarized light to rotate the amount of sugar can be approximately obtained.

CHAPTER X.

SOURCES OF LIGHT.

Light is furnished us by :

a. Heavenly bodies,
b. Chemical combustion,
c. Electricity,
d. Phosphorescence,

Phosphorescent substances are those that after exposure to certain conditions will shine in the dark. This phenomenon may be referred to the following causes :

a. Spontaneous phosphorescence, or that seen in vegetables and animals.
b. Elevation of temperature,
c. Mechanical effect,
d. Electricity,
e. Exposure to the sun's rays.

The sulphate of calcium and strontium are two such substances and will shine in the dark for many hours after exposure to strong light.

BOOK IV.

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CHAPTER I.

ELECTRICITY AND MAGNETISM.

MAGNETISM.

Magnets are bodies that attract iron and the force exerted is called *magnetism.*

Theory of magnetism,

In all bodies two magnetic fluids, called *positive* and *negative*, are circulating in opposite directions among the molecules. In most substances these fluids neutralize each other, but in magnets the *positive* fluid collects at one end of each molecule and the *negative* at the other end.

KINDS OF MAGNETS.

Magnets are either :

Natural,

Artificial,

a. A *natural magnet* or *loadstone* is an oxide of iron Fe_3O_4.

b. *Artificial magnets* may be—

1. Temporary, or
2. Permanent.

Temporary magnets are made of iron which assumes the property of magnets by passing an electric current around the iron. (*see chapter on electro magnets*) or by magnetic induction.

After the exciting cause is removed the iron loses its magnetic properties.

Permanent magnets are made of steel which assumes the magnetic property by passing a strong current of electricity around the steel or by rubbing the steel with a magnet for some time.

After the exciting cause is removed the steel retains its magnetism.

PROPERTIES OF MAGNETS.

Magnets have the following properties :—
Attracting iron,
Assuming a given direction,
Declination,
Inclination, or dip,
Magnetic induction,
Magnetic rupture.

a. The *attracting force* of a magnet is more marked the nearer the ends are ap-

proached, and diminishes toward the centre at which point it is absent.

The *poles* of a magnet are near the ends where the attracting force is the greatest.

The *neutral point* is at the centre of the magnet where the attracting power is nothing.

b. A *magnet* or *magnetic needle*, when freely suspended, *assumes a given direction* with its poles always pointing in the same direction. The poles pointing toward the north is called the *north pole*, while the one toward the *south* is called the *south pole*.

Poles of the same name repel each other while those of opposite name attract each other.

An *astatic needle* is one not influenced by the earth's magnetism and is usually a combination of two needles with poles in contrary directions.

c. *Declination* of magnetic needle. The north and south poles do not point geographically north and south. The amount of declination however is not constant but differs in places and from time to time.

d. *Inclination* or *dip* of the magnetic needle is its tendency when freely suspended to incline from the horizontal plane.

North of the Equator the north pole dips as the geographical pole is approached until, before that point is reached, the needle becomes vertical in direction.

The same is true of the south pole south of the Equator. Those points where the needle assumes the perpendicular, are called the *magnetic poles* of the earth.

e. *Magnetic induction* is that property which magnets have of temporarily making magnets of iron when brought directly or nearly in contact with the iron. Such a temporary magnet has in turn, but to a lesser extent, power of induction on other iron.

As soon as the influence of the permanent magnet is taken away the iron loses its magnetic properties.

f. *Rupture of magnets.* When a magnet is broken into a number of pieces every portion will become immediately a complete magnet in itself.

CHAPTER II.

ELECTRICITY.

Electricity is a physical agent manifesting itself by attraction, repulsion, heat, light, &c. Not inherent in bodies but evoked by a variety of causes as friction, chemical action, &c.

Theories.

1. *Franklin's theory.* All substances contain an imponderable fluid in a quiet state but when excited as by friction a portion of this fluid is drawn off, leaving a preponderance of the other portion which causes the phenomena of electricity.

2. *Timmer's theory.* All substances contain two fluids which ordinarily neutralize each other, but when excited are separated and cause the manifestations of electricity.

Admitting this fluid theory of electricity any body may be charged with an excess of either one fluid or the other, which are called *positive* and *negative* fluids, and from which we have the following law: *Two*

bodies charged with the same electricities repel each other but with opposite electricities attract each other.

CONDUCTORS AND NON-CONDUCTORS.

Bodies in which electricity passes rapidly from one part to another are called *good conductors*, but those bodies in which it does not, are called *poor conductors* or *non-conductors*. Glass is the best non-conductor. *Poor conductors* are also called *insulators*.

CHAPTER III.

KINDS OF ELECTRICITY.

There are two principal kinds of electricity:

1. Statical,
2. Dynamical.

STATICAL ELECTRICITY.

Statical or *frictional* electricity was the first kind of electricity discovered, and is produced by friction.

PROPERTIES OF STATICAL ELECTRICITY.

Statical electricity has the properties of—
Surface distribution,
Rapid dissipation,
Induction.

a. The *distribution* of electricity in any body charged with statical electricity, is upon the surface and has the greatest intensity at the most acute points on that surface.

b. Statical electricity is rapidly *dissipated* from bodies even when they are proper-

ly insulated—that is—mounted on non-conductors.

Electricity is dissipated by—

The air,

Imperfect insulation.

c. There is *induction by statical electricity* as there is induction by magnets. Thus when an insulated conductor is charged with electricity, any body in a neutral state and insulated, placed near it will be acted upon in a manner analogous to that of a magnet upon soft iron. In other words it decomposes the neutral fluid in the body attracting the opposite and repelling the like kind of electricity. This body will in turn have a similar action on other insulated bodies but all will have their electric fluids neutralized again by withdrawing the influence of the charged conductor.

The different kinds of electric fluid—*negative* and *positive*—are collected at the extremities of these bodies charged with induced electricity, while at the centre is a space destitute of free electricity.

CHAPTER IV.

ELECTRICAL MACHINES.

Among the most important of Statical electrical machines are the—

Electroscope.

Glass plate machines,

Electrophorus,

Leyden jar.

a. The *electroscope* is an instrument used for detecting the presence and kind of electricity in a body.

This consists essentially of an insulated metallic rod at the end of which two gold leaves are attached.

If any electrified body is brought near the rod, the electric fluid will be decomposed by induction, and consequently the gold leaves will be charged with one kind of electricity, causing them to diverge, while the opposite end of the rod will be charged with the other kind.

The *presence* of electricity is thus determined by the divergence of the gold leaves

but not the *kind*. This is determined as follows. While the rod is still charged by induction from an electrified body, touch the end of the rod. This will remove one kind of electricity and leave the rod charged with the opposite or other kind. After removing the finger take away the reducing agent and apply to the rod a *positively electrified* body, as an excited brass rod.

If the gold leaves diverge more widely the former body was *negatively* charged, for like electricity will be repelled to the opposite extremity. The reverse is true if the gold leaves are less divergent.

b. *Plate electrical machines* are instruments used principally for storing up statical electricity. The usual form of this machine consists of a circular plate of glass at the upper and lower parts of which are two cushions which act as rubbers when the plate is turned. In front of the plate are two isolated conductors terminating in branches which are bent around the plate between the rubbers and studded with points projecting toward the glass. When the plate is turned or revolved it becomes

charged with *positive electricity* by friction against the rubbers. To equalize this *positive* electricity on the glass plate, *negative* electricity is given off from the conductors through the projecting points, thus leaving the conductors charged with positive electricity.

The cushions are connected with the earth by a metallic chain so that the negative electricity from the plate can escape to the ground. *Holtz* invented a machine by which a body is electrified by friction once for all, and made to act by induction in such a way as to produce a continual generation of electricity, by the rotation of a glass plate. The electrophorus acts on the same principle.

c. The *electrophorus* consists of a disc of resin and a metallic disc with an insulated handle. The resin is electrified by friction and the metallic plate then placed upon it which in turn becomes charged with electricity by induction from the resin. If this plate still in position is touched by the finger the like kind of electricity passes to the ground while the plate remains charged

with the opposite kind. If now removed from the resinous disc by means of the insulated handle it still contains but one kind of electricity and by touching it a spark denotes the union or the neutralizing of the two fluids.

This can be repeated a number of times without again exciting electricity in the resin.

CONDENSATION OF ELECTRICITY.

A *condenser* is an apparatus for storing up a large quantity of electricity on a small surface.

There are a great many forms of condensers, but the *Leyden jar* is the most convenient.

d. The *Leyden jar* consists of a glass bottle, the interior of which is coated with tin foil, and the exterior to the neck of the bottle with the same material. The neck of the bottle is provided with a cork through which passes a brass rod terminating externally in a knob and internally by a chain communicating with the tin foil.

The jar is charged by connecting the external surface with the ground and the in-

terior, by means of the brass knob with the source of electricity. In this way the inner surface of the jar becomes charged with one kind of electricity and the outer by the opposite kind, owing to the law of attraction and repulsion of electrical fluids.

By connecting the outer with the inner coatings of the jar, by means of a good conductor, the two fluids unite or the jar is discharged as indicated by a spark.

It is found by experiment that nearly all the charge of electricity resides on the inner and outer surfaces of the glass and not on the tinfoil, the mutual attraction of the two opposite electricities causing them to approach as nearly as possible, their union being prevented by the poor conductivity of the glass.

The extent of charge for a Leyden jar depends directly upon the extent of surface and inversely upon the thickness of the insulator—glass.

CHAPTER V.

EFFECTS OF ELECTRICAL DISCHARGE.

The electric discharge is the phenomena which accompanies the union of two opposite electric fluids and may be either *continuous* or *sudden*, the difference being one of degree and not of kind.

The effects of the discharge may be either—

Physiological,
Luminous,
Heating,
Magnetic,
Mechanical, or
Chemical.

a. The *physiological effects* consist in a violent exciting action on the sensible and contracting elements of the organic tissues through which it passes.

b. *Luminous effects* often accompany the recombination of the two electrical fluids and manifested by flashes or sparks of light,

the color depending upon the surrounding medium. Its spectrum is full of dark lines.

c. *Heating effects.* The electric spark is the source of intense heat. Gas can be ignited, alcohol set on fire, &c., by the spark coming in contact with it.

d. *Magnetic effects.* By passing the discharge through a coil of wire inside of which a steel needle is placed, the needle will afterward be found magnetic.

e. *Mechanical effects* consist in lacerations, fractures, &c., which follow a powerful discharge of electricity through a poor conductor,

f. *Chemical effects* result in decomposition and recombinations, produced by the passage of the electrical discharge through substances.

Thus gases in proper proportions are made to combine &c., by passing a spark through them.

CHAPTER VI.

DYNAMICAL ELECTRICITY.

The discovery of *Dynamical or current* electricity is due to *Galvani* whose investigations on the influence of electricity on animals especially the frog, led to additional discoveries as to the nature of this form of electricity.

Volta attributed the contractions of the frog's legs in Galvani's experiments to the metal conductor, used to excite these contractions, so he constructed the *Voltaic pile*, which consists of a series of discs of copper, zinc and wet cloth arranged in uniform order,

This experiment worked so well that it led to further investigations which resulted —as the general belief that this form of electricity was due to chemical action—in the construction of *chemical batteries* for the production of electricity.

CHAPTER VII.

CHEMICAL BATTERIES.

In all batteries the metal acted upon is called the *positive* and the other the *negative* plate.

If these two plates are connected with a wire the *direction* of the current is determined by the *positive* metal—that is, the current always passes *from* the *positive* to the *negative* in the fluid, and from the *negative toward* the *positive* out of the fluid.

By the *direction* of the current is always meant the direction of the *positive* current, or the one above described. The *negative* current always takes the opposite direction, but for all practical purposes it is never considered.

If the wire connecting the two plates be divided, the electricity collects at the divided ends, hence these are called the *poles* or *electrodes*.

The *positive electrode* is always the one connected with the *negative plate*, while the

negative electrode is connected with the *positive* plate.

KINDS OF BATTERIES.

Among the many batteries constructed the following are the most important :

The simple battery,
Daniell's battery,
Grove's battery,
Bunsen's battery,
Gravity battery,

a. The *simple battery* consists of a plate of copper and one of zinc suspended in a weak solution of sulphuric acid. The chemical action which results causing the production of electricity is as follows :—

Sulphuric acid. *Zinc.* *Hydrogen.* *Zinc Sulphate.*

$$H_2 (SO_4) + Zn = H_2 + Zn (SO_4.)$$

The *zinc* is the *positive* and the *copper* the *negative* plate.

This form of battery is seldom used, for the current rapidly diminishes until after a few hours it ceases to act at all.

This diminution is due to the following causes.

1. Decrease of chemical action.

2. Local action.

3. Polarization of negative plate. *Local action* is the production of small closed circuits of electricity in the positive plate, due to impurities.

This can be prevented to a certain extent by *amalgamating* the zinc, that is rubbing it over with metallic mercury.

Polarization is the formation of hydrogen gas on the copper plate thus interfering with the contact between the fluid and the metal. The hydrogen also decomposes the zinc-sulphate causing a deposit of metallic zinc on the copper.

b. *Daniell's battery.* This consists of a glass vessel filled with a solution of sulphate of copper in which is immersed a cylinder of copper and crystals of the sulphate of copper.

Inside the cylinder is a porous earthen cup containing a weak solution of sulphuric acid suspended in which is a cylinder of zinc. The chemical action resulting is as follows :

Sulphuric acid.		*Zinc.*		*Zinc-Sulphate.*		*Hydrogen.*
$H_2 (SO_4)$	+	Zn	=	Zn (SO_4)	+	H_2

Hydrogen. Copper-sulphate. Copper. Sulphuric acid.

$$H_2 + Cu(SO_4) = Cu + H_2(SO_4.)$$

In this way the hydrogen decomposes the sulphate of copper, thus preventing the polarizing of the copper plate, and the sulphuric acid formed replenishes that which is decomposed by its action on the zinc. The sulphate of copper which is decomposed by the action of the hydrogen is replenished by the undissolved crystals.

c. *Grove's battery*. This consists of a glass vessel filled with diluted sulphuric acid, immersed in which is a cylinder of zinc.

Within this cylinder is a porous earthen cup containing nitric acid, suspended in which is a plate of platinum. The following chemical action results :

Zinc. Sulphuric-acid. Zinc-sulphate. Hydrogen.

$$Zn + H_2(SO_4) = Zn(SO_4) + H_2.$$

Hydrogen. Nitric-acid. Water. Nitrous-acid.

$$H_2 + HNO_3 = H_2O + HNO_2$$

The nitrous-acid fumes pass off in the air.

d. *Bunsen's battery* is the same as *Grove's* except the platinum is replaced by a carbon plate, the chemical action being the same.

e. *The chromic acid batteries* are like *Bunsen's* and *Grove's*, except the nitric-acid is replaced by chromic acid or a solution of bi-chromate of potash in sulphuric acid. The hydrogen decomposes the chromic acid forming oxide of chromium, thus doing away with the nitrous acid fumes which are disagreeable.

f. The *gravity battery* consists of a glass vessel in the bottom of which is a copper plate covered with crystals of sulphate of copper. The vessel is then filled with water and a zinc cylinder immersed in it. The chemical action is the same as seen in *Daniell's* battery.

The sulphate of zinc which forms, floats on the surface of the sulphate of copper, owing to its lower specific gravity and the battery thus replenishes itself. In all these forms of batteries, a single cell is called an *element*, but a combination of cells a *battery*.

In combining the cells, the positive plate in one is connected with the negative in another by means of a wire, and so on from one element to another, until all the cells are joined. Increase the number of ele-

ments and in this way increase the *strength* of the current.

If on the contrary all the same kind of plates in the elements are joined together, we increase the surface acted upon, and in this way the *quantity* of electricity produced is proportionally increased.

CHAPTER VIII.

DIRECTION AND MEASUREMENT OF CURRENT ELECTRICITY.

The *direction* and *measurement* of voltaic currents of electricity are determined by the magnetic effects they produce.

If a wire is suspended horizontally in the direction of a magnet, and a current be passed through this wire, the needle is deflected and tends to take a position which is more nearly at right angles to the magnetic meridian in proportion, as the current is stronger.

If the observer imagine himself the wire, the current entering his feet and passing out of his head, and his face always toward the needle; the north pole of the needle will always be deflected toward the left of the current.

The *Galvanometer* is an apparatus by means of which the direction and intensity of currents can be determined and is based upon the above principle of deflec-

tion of the needle by the current. If, however, instead of having a single wire, a complete circuit is formed around the needle or several such circuits are made, the effect is multiplied.

INTENSITY AND RESISTANCE OF THE ELECTRO-MOTOR FORCE.

The *Electro-motor force*, is that force by which electricity is set in motion, and its intensity and resistance are governed by the following laws :

a. *The intensity of a current is equal to the electro-motor force, divided by the resistance ; and is inversely proportional to the length, and directly to the section of the conductor.*

b. *The resistance of a current is inversely proportional to the intensity of the current, and section of the conductor and directly as the length of the conductor.*

In the ordinary element there are two resistances to be considered :

a. *Internal* or resistance of the fluid.

b. *External* or resistance due to the passage of the current outside the liquid.

CHAPTER IX.

EFFECTS OF CURRENT ELECTRICITY,

The effects of current electricity may be :

Magnetic.

Heating.

Luminous.

Physiological.

Chemical.

a. The *magnetic effects* have already been considered.

b. Heating effects. The heat disengaged in any given time is directly proportional to the square of the strength of the current and to the resistance.

A battery of thirty Bunsen elements will melt copper wire, hence the thermal effect of the current is used for firing mines, cauterizing, &c.

The *heating effects* depend more upon the size of the plates than upon the number of them when the resistance is not great.

c. *Luminous effects.* In making and breaking a voltaic current at the point of contact a spark is obtained. If at the two terminals of a strong battery, pencils of carbon are placed near together, and an intense current passed, the pencils become incandescent, and a luminous arc extends between the two points called the *voltaic arc.*

The electric light has the same chemical properties as solar light. Its spectrum has several bright lines.

d. *Physiological effects.* The voltaic current has the property of causing contraction of all protoplasmatic matter, and excitement throughout the nervous system. These effects are only produced at the opening and closing of the circuit.

e. *Chemical effects.* Many substances are decomposed into their elements by the voltaic current. This decomposition is called *Electrolysis.* The positive electrodes effecting this electrolysis is called the anode, and the negative, the kathode.

Many substances previously considered elements, have by *electrolysis* proven to be of a compound nature. In the decomposition of salts the acids are liberated at the

anode, and the bases at the *kathode*. Electrolysis cannot take place in substances unless they are conductors.

ELECTRO METALLURGY.

Electro metallurgy or *galvano-plastics*, is the decomposition of salts by which certain metals are precipitated on the negative plate. In this way electro gilding is done.

CHAPTER X.

ELECTRO DYNAMICS.

Electro dynamics treat of the laws of electricity in a state of motion or the action of electric currents on each other and on magnets. *Two currents parallel and in the same direction attract each other, but in contrary directions repel each other.*

Currents impart the same rotatory motion to magnets that they do to currents, but not only do currents act upon magnets but magnets also act upon currents, causing them to rotate when the magnet is fixed.

The earth which exercises a directive action on magnets acts also on currents. Thus every vertical current tends to place itself, under the earth's influence, in a plane perpendicular to the earth's magnetic meridian, but every horizontal current tends to have a continuous rotatory movement rather than a directive one.

Not only has the earth a directive tendency on a freely movable current, but also causes, as in the magnet, an inclination or dip of a circuit when it is properly balanced.

MAGNETIZATION BY CURRENTS.

Electro magnets are bars of soft iron which under the influence of a voltaic current become magnets. But this magnetism is only temporary, for so soon as the current ceases the iron is no longer a magnet, or if at all, a very weak one, the magnetism remaining being called *residual.* These electro magnets are usually made in the horseshoe form, and the insulated copper wire is wound around the two armatures in the same direction, so as to form bobbins.

As a general rule *electro magnetic force or strength is directly proportional to the strength of the current, and to the number of windings of the wire, but independent of the nature and thickness of the wire.*

It is on the principle of the electro magnet that all telegraphing is done.

CHAPTER XI.

VOLTAIC INDUCTION.

Induction by the Voltaic current is the action which currents or magnets exert on conductors.

Induction can be produced by :

Magnets.

Interrupted currents.

Continuous currents.

A current upon itself.

a. If a *magnet* be introduced into the centre of a hollow coil of insulated wire, at the moment of introduction and withdrawal a momentary current will be excited in the coil of wire. These excited currents are opposite in direction.

b. Induction by *interrupted* currents can be produced by introducing an insulated coil of wire, called *primary*, into another insulated coil, called the *secondary*, and passing a current of electricity through the primary.

At the moment of making and breaking this current a *secondary current* will be excited in the *secondary coil* but in opposite directions, *viz.:* at the moment of *making* in the *inverse* direction to that in the *primary coil* and in the *same* direction at the time of *breaking*.

c. By *continuous currents*. When a primary coil is traversed by a continuous current and brought near a *secondary coil* or is removed from it, currents are excited in this secondary coil as seen in (*b*).

d. Induction can be excited by a *current on itself* when two portions of the same insulated wire are placed side by side, the sudden making and breaking of a current in one wire will excite a current in the other called *extra*. The making of this current is a hindrance to the passage of electricity throughout the length of the wire, for the *extra current* is an inverse one, but the breaking intensifies the current as it is in the same direction as the current itself.

By placing a core of soft iron in the interior of any of the coils above mentioned for the production of induced currents, the effect will be intensified, the iron acting as

a magnet when the current is transmitted around it.

The following law governs induced currents. *The strength of the induced currents is proportional to the inducing currents and to the products of the lengths of the inducing and induced currents.*

APPARATUS FOUNDED ON INDUCTION.

The following apparatus is founded on induction:

Magneto-electrical machines.

Induction coils.

Telephone.

a. The *magneto-electrical machine* in its simplest form consists of a horse shoe magnet around which two bobbins are made to revolve. The wire forming these bobbins is coiled on two cylinders of soft iron jointed by plates of iron or brass, thus forming *electro-magnets.* So that the induced currents produced, may be in the same direction, the wire on the bobbins is coiled in opposite directions. By each complete revolution of the electro-magnet, its two armatures become alternately magnetized in contrary directions, and in each wire an induced current is produced, the direction

of which changes at each half turn. By aid of a *communicator* the currents may all be made to pass in the same direction.

b. *Induction coils*, of which *Ruhmkorff's* is a good example, are arrangements for producing induced currents of electricity by means of electric currents whose circuits are opened and closed alternately in rapid succession.

These coils consist essentially of hollow cylinders in which are placed bundles of iron wire. Each cylinder has two helices, coiled around it one connected with the poles of a battery, the current of which is alternately opened and closed by a self-acting arrangement, and the other serving for the development of the induced current.

By means of an apparatus of this kind, currents of electricity are produced superior in effects to those obtained by *electrical machines* or *Leyden batteries*. In *Ruhmkorff's machine* there is placed in the bottom a *condenser* made of tin foil so insulated that each alternate layer, forming one coating, is connected with the inducing current, thus storing up some of the electricity from the battery and *extra currents*; while the remain-

ing layers, forming a second coating, are connected with the secondary or induced currents, thus increasing their strength by using this stored-up electricity.

c. The *telephone* is an instrument whose action depends upon the fact, that whenever the relative positions of a magnet and a closed coil of wire are altered there is produced within the coil a current of electricity. The magnet and the coil in the telephone remains fixed, but the iron membrane or diaphragm in the mouthpiece, which vibrates backward and forward when spoken into, becomes magnetized by induction from the magnet. These vibrations give rise to currents in the coil surrounding the permanent magnet, which are transmitted through the circuit to the distant coil surrounding its magnet which in turn alternately attracts and ceases to attract the corresponding diaphragm, thus producing similar sounds by exciting vibrations in the air.

CHAPTER XII.

THERMO-ELECTRIC CURRENTS.

Currents of electricity can be produced by applying heat or cold to one of the junctions of a circuit composed of different metals.

The electricity thus produced is called *Thermo-Electric currents*.

In the *thermo-electric pile* a large number of elements or metals are used in a small space and alternately soldered together.

The elements may be of many kinds, or better still, many elements of the same kind.

APPENDIX.

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METEOROLOGY.

Meteorology treats of the phenomena produced in the atmosphere.

By the *climate* of a place is understood the whole of the meteorological condition to which the place is subjected. The *mean temperature* for a day is that obtained by adding together twenty-four hourly observations, and dividing by twenty-four.

Causes modifying the temperature of any place.

The temperature of any place is modified by its:

Latitude.

Height.

Direction of wind.

Nearness to the sea.

Nearness to the gulf stream.

a. The influence of *latitude* on the temperature arises from the greater obliquity of the solar rays the further North or South

of the Equator any place is situated, and consequently a less quantity of heat is absorbed.

The length of day influences the temperature in Northern countries, and makes this temperature more uneven than in those countries where the days and nights are nearly equal.

b. *Height.* In the temperate zone a diminution of 1°C corresponds in the mean temperature to an ascent of every 180 yards.

c. *Winds* coming from hot or cold countries influence the temperature of a place greatly.

d. *Nearness to the sea* tends to raise the temperature of neighboring places and render it uniform.

e. The *Gulf stream* exerts an influence like the winds from hot countries.

The temperature of the air on the surface of the Globe is subject to perturbing causes, so purely local and varied, that the *isothermal lines* encircling the earth are greatly curved.

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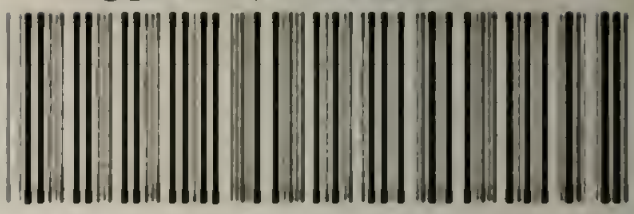

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